D-A101 312 NAVAL RESEARCH LAB WASHINGTON DC F/G 13/9
EVALUATION OF FOUR DRIVE CHAINS FOR SERVICE IN SEA WATER.(U)
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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NRL Memorandum Report 4560
2. GOVT ACCESSION NO.: AD-A101 312
3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): EVALUATION OF FOUR DRIVE CHAINS FOR SERVICE IN SEA WATER
5. TYPE OF REPORT & PERIOD COVERED: Interim report
6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Fred R. Stonesifer
8. CONTRACT OR GRANT NUMBER(s): 9 Jul 81
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Research Laboratory, Washington, D.C. 20375
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: OMN; NAVSEA, M000-0; NRL Prob. No. 58-M001-X-0
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Sea Systems Command, Washington, D.C. 20362
12. REPORT DATE: July 9, 1981
13. NUMBER OF PAGES: 9
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): NRL-MR-4560
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Roller chain
Leaf chain
Sea water environment

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Four types of drive chains (two roller chains and two leaf chains) were evaluated for use in sea water environment. The chain pins were tested in static three-point bend tests. Sections of the chains were cyclicly loaded to failure after being sustained under static loading for two or four weeks in sea water. The strongest 3×4 leaf chain also provided the longest life at the chosen cyclic loads.

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

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CONTENTS

EVALUATION OF FOUR DRIVE CHAINS FOR SERVICE IN SEA WATER

I. INTRODUCTION

The Navy has an application in which roller-chain drives are subjected to relatively high loads in sea water environments. The chain experiences a steady load with occasional low-frequency cyclic loading superposed. The apparatus is moved in and out of sea water at varying intervals. An earlier study at NRL [1] analyzed some in-service failures and performed tests on the type of roller chain presently being used in this application. The current study is a follow-on to the previous work and is intended to evaluate the relative merits of four candidate chains. The chains under consideration included the type presently being used and three possible replacements.

The type of chain presently being used and studied in the earlier work [1] is a standard commercial #50 roller chain. The low carbon steel pins in this chain are case hardened for wear resistance. NRL [1] found that the pins have a fine grained martensitic microstructure to a depth of 0.020 to 0.025 inch. This case has a hardness of 63 on the Rockwell C scale. The remainder of the pin cross-section is a coarser martensite with a hardness of 45 on the Rockwell C scale. The manufacturer's catalog lists an average breaking load of 6600 pounds for the #50 chain. One likely candidate for replacing this present chain is the #625 roller chain produced by the same manufacturer. The #625 chain is identical in size and configuration to the #50 chain. However, the pins in the #625 roller chain are made from a medium carbon steel and through hardened to near 50 on the Rockwell C scale. The company catalog states that the #625 chain has an average breaking load of 8000 pounds. These two roller chains would be completely interchangeable and would not necessitate changing the present sprockets or redesigning for additional clearance.

Manuscript submitted May 8, 1981.

The other two chains being considered as possible replacements for the present chain are of another configuration and differ in size. These are commonly called leaf chains and are assembled by linking together identical plates with pins. The smaller of the two leaf chains is denoted as a 2×3 chain since the alternate links consist of either two or three plates. The manufacturer quotes an average breaking load of 9000 pounds for the 2×3 leaf chain. The larger leaf chain is called a 3×4 chain since its alternate links consist of either three or four plates. The manufacturer quotes an average breaking load of 13,600 pounds for this larger chain. Both leaf chains were made by the same company, but not the company that made the two roller chains. The leaf chains were made with pins of larger diameter than those in the roller chains, but within the same hardness range as the #625 roller chain pins.

II. TESTING PROGRAM

The test program specified two basic types of tests for each of the four chains in sea water environment. In one series of tests individual chain pins were to be loaded in three-point bending with a sustained load until failure or 200 hours time under load in sea water was accumulated for each chain pin. These tests were then to be repeated with pins that had been scored to represent possible material or machining defects. The original plan specified a constant load of 1500 pounds. This was increased to 2000 pounds after it was learned that the pins from the chain with the lowest breaking strength (#50 roller chain) could endure over 200 hours at the lower load. In order that this series of tests have any value, it was mandatory that failures occur in at least one of the chains being tested.

The second series of tests were designed to assess the relative fatigue lives of the four chains subjected to cyclic loading in sea water. Prior to cyclic loading, a length of each chain was to be maintained under constant 2000 pound load for periods of both two weeks and four weeks while submerged in sea water. Specimens from these lengths of chain were to be cycled between 2000 and 3500 pounds, in a sea water environment, to failure or until at least 10^5 cycles had been endured.

The "sea water" for use in these tests was produced from a commercially purchased synthetic mixture of sea salts which was mixed with tap water in the prescribed proportion. In this test series identical loads were applied to each chain. Loads were not scaled to produce equal stress or percentage of breaking load. The loads are representative of the in-service conditions for the particular application.

III. TEST DETAILS AND RESULTS

A new, unused, length of each of the four chain types described earlier was ultrasonically cleaned in carbon tetrachloride (CCl_4) to remove grease and oils. This treatment put all the specimens on the same base simulating the worst in-service condition. All pin and chain specimens were taken from these degreased lengths of chain.

In the static bend tests of the chain pins, each individual pin was loaded by inserting it through holes in three thin steel plates. The outer two plates were spaced with one-half inch between their center lines and fixed to a load cell. The third plate was spaced in the center of the other two and loaded to maintain a 2000 pound load at the load cell. Loading was in an electro-hydraulic closed-loop testing system. This subjected the pin to three-point bending with a major span of 0.5 inch and a load of 2000 pounds. The roller chain pins were 0.200 inch in diameter which produced a calculated maximum outer fiber stress of 318 ksi. The leaf chain pins were 0.235 inch in diameter, so were subjected to a calculated maximum outer fiber stress of 196 ksi. Sea water was dripped constantly on each pin while it was under load. The only pin to fail during these test conditions was from the #50 roller chain. One unnotched pin from the #50 roller chain failed after 33.1 hours but another survived over 200 hours at load. The notched specimens were scored circumferentially near the center of the pin's length. These notches were about 0.003 inches deep and were produced by pressing a 0.003-inch diameter diamond-impregnated wire against the pin while it was spinning in a lathe. One notched pin from the #50 roller chain failed after only 9.0 hour at load, but the other one could not support the 2000 pound load and failed instantly. All of the other pins tested, both notched and unnotched, exceeded 200 hours under load.

Segments of each chain were loaded to 2000 pounds constant load for periods of two and four weeks. These chains were submerged in sea water and loaded through carefully calibrated air cylinders supplied with pressure-regulated nitrogen gas. After the desired time under load was achieved, specimens of approximately 7.5 inches in length were cut from each chain segment. These specimens were cyclicly loaded on a sinusoidal load-time profile of 3 Hz between loads of 2000 and 3500 pounds. Sea water was dripped over the specimens during cyclic loading. All specimens tested in this manner failed with results as tabulated in Table 1. The series of specimens which failed under cyclic loading, after a two-week period with static loading, are shown in Figure 1.

It is important to note that the failures in the roller chains are identical to those which occurred in the #50 chain while in service. In the earlier NRL study [1] the chains were not pre-conditioned at a constant load before fatigue testing and the in-service type chain failures were not reproduced. The earlier laboratory fatigue failures [1] occurred consistently in the link plates rather than in the pins. After time-under-load in sea water, all the laboratory failures in the roller chain were pin failures. This would seem to indicate that small cracks are initiated in the pins during static loading and then grow to cause failure during cyclic loading. This is especially damaging for the case hardened pins of the #50 chain. The harder outer case is more susceptible to cracking and such cracking greatly reduces the strength of the pin. The through-hardened pins of the #625 chain are less brittle on the outer surface so should be more resistant to crack initiation.

The larger diameter pins of the two leaf chains were not as highly stressed and failure still tended to initiate at the pin holes in the chain plates. After several of these plates had failed the pins experienced more bending load (as opposed to shear loading) and they too eventually failed producing combination plate and pin failures as shown in Figure 2. Pin failures were more likely in the more highly stressed 2×3 leaf chains. The 3×4 leaf specimens all failed either in the plates or in a pin-plate combination.

IV. CONCLUSIONS

Results of this study indicate that replacement of the #50 roller chain with any of the other three would be an improvement offering an advantage in both breaking strength and fatigue life. Since replacing the #50 chain with the #625 chain would not involve any other change or redesign, it seems logical that this should be the first and immediate action. This substitution would give an increase of 18% in the quoted static breaking strength and more than double the expected fatigue life. This replacement should up grade the present marginal system to an acceptable operating life without costly redesign. If this still proves to be unsatisfactory it may then be necessary to redesign for use of the 3 × 4 leaf chain.

REFERENCE

1. Stonesifer, F. R., Smith, H. L. and Meyn, D. A., "Failure Analysis of Roller Chain Drives," NRL Memorandum Report 4202, April 4, 1980.

Table 1: Data on Cyclic Loading of Four Types of Drive Chains

Type of Chain	Listed Catalogue Breaking strength (lb)	*Cycles to failure* with sinusoidal load between 2,000 & 3,500 lb at 3 Hz in sea water				
		After 2 weeks at 2,000 lb static load in sea water		After 4 weeks at 2,000 lb static load in sea water		Over all Average
		Individual Specimens	Average	Individual Specimens	Average	
#50 roller	6600	33,780 50,410	4.21×10^4	29,830 40,120	3.50×10^4	3.86×10^4
#625 roller	8000	97,270 88,040	9.27×10^4	61,090 82,000	7.15×10^4	8.21×10^4
2 × 3 leaf	9000	78,320 94,830	8.66×10^4	104,910 76,820	9.10×10^4	8.88×10^4
3 × 4 leaf	13600	141,120 155,030	14.81×10^4	158,760 139,760	14.39×10^4	14.60×10^4

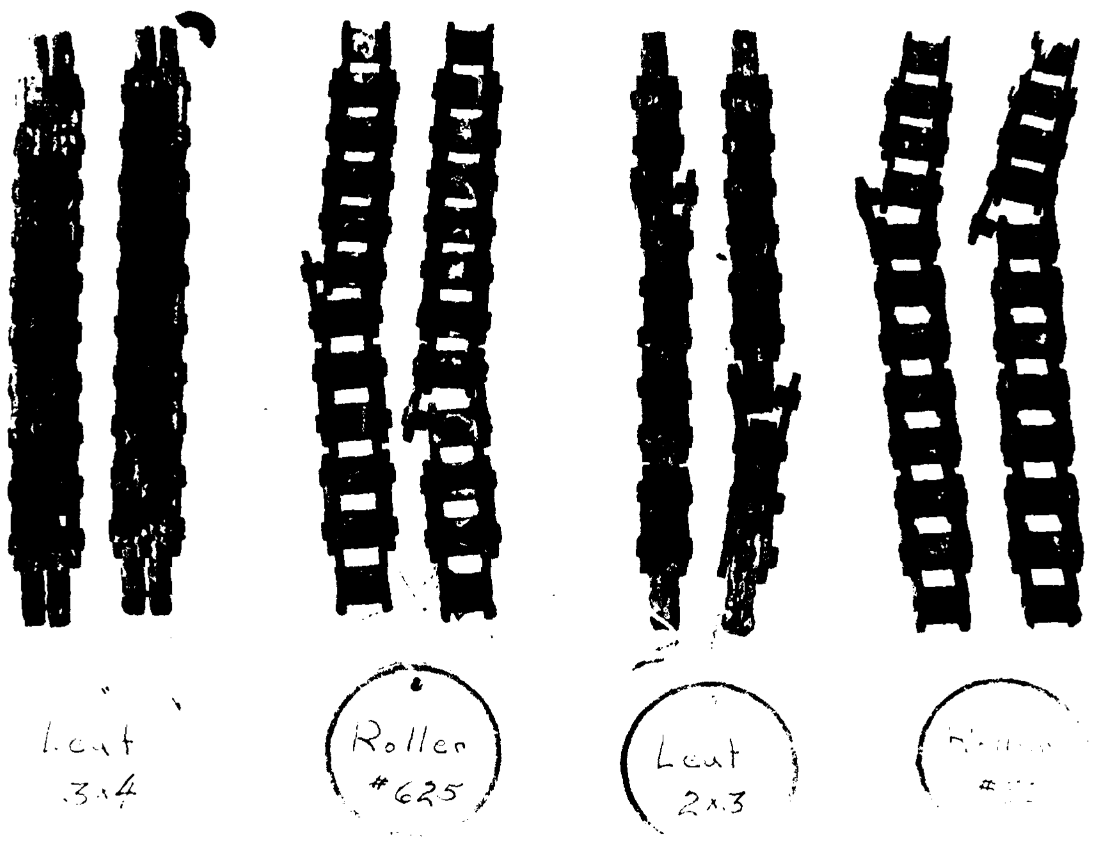

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Fig. 1 — Specimens of four types of chains failed by cyclic loading after two weeks of sustained static loading in sea water.

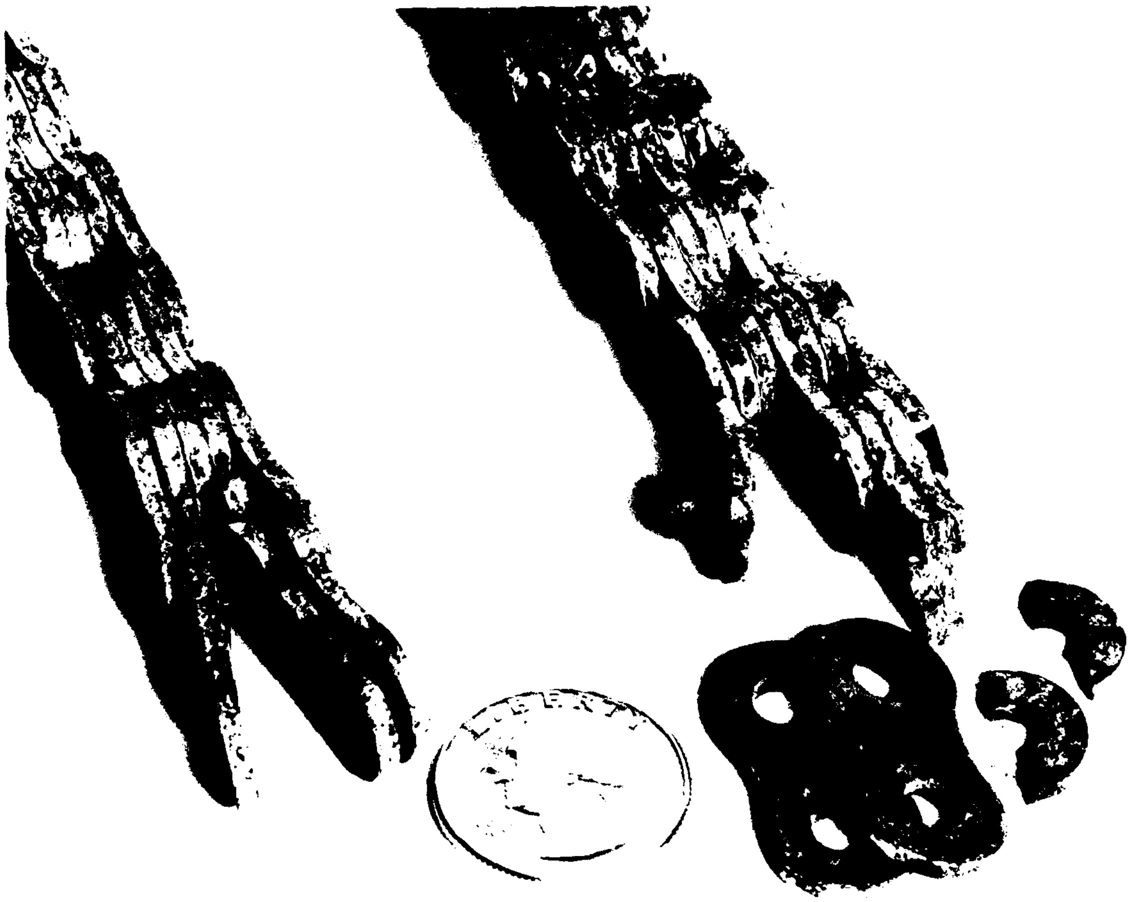

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Fig. 2 — Combination plate and pin failures occurring in leaf-chain specimens subjected to cyclic loading after four weeks of sustained static loading in sea water.